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A MULTI-USER BIOMEDICAL LABORATORY DATA ACQUISITION SYSTEM,(U)
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A MULTI-USER BIOMEDICAL LABORATORY DATA ACQUISITION SYSTEM

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ABSTRACT

A unique multi-user computer system for data acquisition and experimental control is now in use at the US Army Research Institute of Environmental Medicine at Natick, MA. Based on a 32K PDP-11/40 which is running the multi-task executive RSX-11M, the system provides real-time data acquisition and control for several independent biomedical experiments simultaneously. The system handles analog I/O (64 channels in, 10 out) through the LPS 11, switch closure input, relay closure output, parallel binary or BCD I/O (DR 11 interface) and TTY I/O (DL 11 interface). Analog and digital signals are carried to and from approximately 20 laboratories in the building via cables of 11-pair individually shielded wire. Instrumentation amplifier modules (Analog Devices AD610J) preceded by passive filter networks are used at the computer end to isolate and filter each analog input channel at a cost of approximately $50/channel. Applications which have been developed include: analysis of myocardial contractility, breath-by-breath respiratory parameter evaluation, temperature (skin and rectal) measurement and digitizing of miscellaneous graphical data. No automatic control is presently being done, but on-line manual control is being done based on data fed back to the labs in the real time from the computer.

One of the unique features of the system is its central role in a serious attempt to integrate the computational facilities available to this research institute. The PDP-11 was rapidly and easily interfaced to a local Univac 1106 by making it simulate a 300 baud asynchronous terminal. This interface will eventually be upgraded to a high speed synchronous link. At the other end of the spectrum, Hewlett-Packard 9800 series programmable calculators are being connected to the PDP-11 via DL 11 interfaces to form a hierarchy which will provide local computation, data acquisition and control capabilities backed by the full file storage and computational power of a large scale computing system.

The US Army Research Institute of Environmental Medicine (USARIEM) is a relatively small (about 150 employees) medical research organization dedicated to heat, cold, high terrestrial altitude and physical fitness studies. This diversity of research goals requires a wide diversity in experimental technique ranging across human studies and animal models, basic physiology and external human performance measures, in vivo and in vitro experiments.

Approximately two years ago the Institute began to assemble a central computer staff and equipment for data acquisition, reduction and analysis. Evaluation of requirements resulted in the installation, about nine months ago, of a DECLAB 11/40 system for data acquisition and control functions. Primary design features in configuration and use of this system have been the following:

a. The computer functions as a multi-task facility which should be available seven days a week, twenty-four hours a day with a minimal requirement for scheduling of experiments, i.e., the computer should be available when the scientist needs it, he should not have to schedule his experiment around its availability.

b. The computer interfaces with a wide variety of laboratory instruments, both analog and digital for on-line data acquisition and control.

c. Software is written almost entirely in a high-level language (FORTRAN) in recognition of the fact that most applications are transient and software is very costly.

d. This computer functions as the central link in a distributed processing system which will grow in a variety of directions with time.

Nine months after installation of the computer substantial parts of these objectives have been met and still others have been demonstrated but not fully implemented. Development has progressed far enough to conclusively demonstrate the viability of such a computer system in the biomedical research environment. It is presented at this time, admittedly unfinished, in order to stimulate a dialog from

which its own design as well as the design of other laboratory computer systems may benefit.

The Multi-Task Environment

Central to the development of this facility has been the perspective of industrial process control computers which monitor and control many concurrent independent processes. In contrast to this, most of the scientific application of minicomputers in the past ten years has developed in the direction of use of small minicomputers as personal scientific instruments by individual scientists. While these computers have provided significant benefits, serious problems have also arisen.

First, the requirement to cut costs for "personal" computers has led to minimal configurations requiring exhorbitant amounts of programming effort. It has not been unusual to see a scientist spend ten thousand dollars on a PDP-8 level machine with 4K to 8K of core and no high speed input/output and then invest several man-years of labor (often his own) writing assembly-language code and interacting with the machine through a ten character per second Teletype using a two or three pass assembler.

Second, the scientist has needed a highly significant application in order to justify purchase of a dedicated computer. Thus the individual with a small application or a one-time need has not had free access to a data acquis'tion computer unless he happened to have an associate who owned a computer with whom he worked out a deal.

Third, brief but large jobs still could not be done on such machines, and the individual who bought one found himself constantly working to squeeze things in and constantly working to expand the machine. Modern programmable calculators, while they avoid some of the above problems often suffer greatly in this regard.

Solution: pool resources and buy a bigger computer. New Problem: scheduling experiments around the availability of the computer. Conclusion: a simple background-foreground executive is inadequate. Enter: RSX-11M.

Early in the applications survey at USARIEM several potential applications for the computer were identified which would not use a large quantity of the computer's resources but would require continuous monitoring over long periods of time. Some of these were: temperature control in environmental chambers, test subject body temperature monitoring, data acquisition and reduction for respiratory experiments, and treadmill control. Most of the data acquisition applications within this Institute require a sampling rate significantly lower than 100 samples per second.

The RSX-11M operating system has provided the multitask capability required, and has basically proven to be highly satisfactory. One important feature of RSX-11M is the ease with which independent tasks can share key resources such as the LPS-11. Another is the facility for inter-task communication both of flags and blocks of data. Executive services, particularly the capability to schedule, reschedule and abort tasks both from the console and from other tasks, are extremely useful. In developing the USARIEM data acquisition system extensive use of these capabilities of RSX-11M has paid off heavily in productivity.

Potential users should, however, be aware of the fact that FORTRAN programs written under RSX-11M are very large. Most useful data acquisition programs which interact with one or two files, a terminal, and the LPS-11 require 12K-14K words of core. Our present configuration, with 32K words of core, has proven to be totally inadequate for effective multitask utilization. Plans are now underway to acquire an additional 32K words of core. It is important to note that this problem arises not from unusually sloppy coding in the executive, but primarily as a consequence of its generality. Any complex multitask operating system offering comparable device-independent I/O and similar features will generate comparable size programs. While the situation may improve a little in future versions of the executive, the best solution is to buy a lot of core.

The requirement for high-speed data acquisition (sampling any signal in excess of 100/second) is presently being met by scheduling such experiments for exclusive use of the machine. As core is expanded and more continuous applications are added to the system this will become impossible. Such applications will be done on dedicated processors which will rely on the central processor for support, particularly mass storage and program development.

Interface to Instruments

USARIEM is housed in a single, four-floor building. Signals are transmitted to and from the data acquisition facility via a system of cables which is being installed throughout the building. At present the cabling is installed in approximately eight laboratory areas, and is being expanded to approximately twenty laboratory areas. The cable now being used is 11-pair, each pair individually shielded. The entire installation will require approximately 6000 feet of this cable, of which approximately 2500 feet are presently installed. All cables will be terminated in the computer room on a patch panel by which they can be patched into any analog or digital input or output point on the computer side of the patch panel. The patch panel will also allow access to an intercom system and some instruments for visual monitoring of signals (DVM, counter, oscilloscope).

Ground loops are a serious problem since each instrument is grounded in its own laboratory area and there is no way to make all these grounds identical. This problem has been successfully solved by establishing the policy that all signals to and from the computer will be high-level (i.e., volt, not millivolt), low impedance signals, and instrumentation amplifier modules (Analog Devices AD610J) are used at the computer end of all of the analog signals for differential input. A four-channel prototype for this has been wired and tested with excellent results and additional channels are being added. Filtering is presently done with simple R-C passive filters. The use of active filters for more stringent filtering requirements has been considered as a future possibility. Another feature now being developed is a display for out-of-range indication on analog signals. By adding two comparators and two LED's to each analog channel a simple and inexpensive indication can be provided on a central

display panel for all analog signals out of range.

Laboratory personnel assume responsibility for providing a signal to the computer which is properly scaled and zero-offset as necessary to fall within the -5 to +5 volt range of the computer's analog inputs. To enable them to do this an interface box for use in each laboratory is being built. This box contains several channels (as needed) of operational amplifiers with 10-turn potentiometer controls for gain and zero offset. It also contains a digital panel meter which can be switched to any one of the channels for simple calibration and/or monitoring. Some filtering capability may be provided in this unit as well. A prototype for these units is now under construction.

Many laboratory instruments now provide digital outputs in TTL compatible form. This system will accept these inputs as asynchronous serial communication devices through DL-11 interfaces. Modules are now available (Analog Devices SERDEX modules) at reasonable prices which can convert from parallel binary to bit-serial form. These modules have been procured for one application now under development and will be installed and tested within a few months. Such digital inputs as well as all switch closure inputs are being isolated from the laboratory grounds by optical isolators.

Software

Except for one application which has a segment written in *assembly language* ALL *software* is now and will always be written in FORTRAN. Applications in this Institute are highly fluid, changing monthly if not weekly. At present there are only three people on the computer staff associated with the PDP-11, one of which is primarily an operator. Since this staff is not expected to expand significantly the software production must be efficient and effective.

Distributed Processing

In addition to its role as a data acquisition and control computer the PDP-11 has a major role in the integration of computing resources at USARIEM. From the beginning of the system design the PDP-11 has never been considered as a stand-alone computing facility, but as a key node in a computing resource. The computing resource is seen as a totally open-ended collection of equipment which can be marshalled to solve a problem.

Soon after the PDP-11 was installed an attempt was made to interface it with the Univac 1106 which has provided primary data processing support to this Institute. The first interface which has been successfully used but is slow and awkward involves simulation of an ordinary 300 baud terminal to the Univac. This method was chosen because it required no new hardware at either the PDP-11 or the Univac and required no action on the part of the Univac systems personnel. This interface is being upgraded to 1200 baud shortly and to a synchronous link at some further distant time. Meanwhile the existing transmission capability is being actively used, primarily to transfer data from the PDP-11 to the Univac for statistical analysis and long term storage.

On the other end of the spectrum an experiment is now in progress to interface Hewlett-Packard 9800 series calculators to the PDP-11. The hardware part of the interface has been procured and tested. It consists simply of the asynchronous communication ROM for the H-P 9820 calculator coupled through a pair of modems or a null modem to a DL-11 interface on the PDP-11. Transmission between the two is trivial, but the protocol and content of the transmissions need to be defined in such a way that the calculator operator can assess PDP-11 resources simply.

In an earlier section the dedication of processors to individual experiments requiring high data rates was mentioned. Networking software such as DECNET now makes it possible to implement a distributed processing system with a high degree of flexibility without rewriting the executive. Extensive use of distributed processing is anticipated in the future of this system.

Conclusion

A shared on-line computer system for data acquisition and control can be effectively used in a biomedical research laboratory. While management aspects and politics are beyond the scope of this paper they must not be treated lightly if the system is to be widely used by scientists. Not every laboratory will want a system of this kind, but those who do can build one at a reasonable cost, in a reasonable time, and it will work.

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REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: M 20/76
2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle): (6) A Multi-User Biomedical Laboratory Data Acquisition System
5. TYPE OF REPORT & PERIOD COVERED
6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): (10) John L. Szurek, CPT, MSC
8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS: US Army Research Institute of Environmental Medicine, Natick, MA 01760
10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: (16) 3A161102B71R
11. CONTROLLING OFFICE NAME AND ADDRESS: US Army Research Institute of Environmental Medicine, Natick, MA 01760
12. REPORT DATE: (11) December 1975
13. NUMBER OF PAGES: 3
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office): (12) 6p.
15. SECURITY CLASS. (of this report): UNCLAS
15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Distribution of this report is unlimited

(14) USARIEM-M-20/76

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Submitted for publication in the Proceedings of the Digital Equipment Computer Users Society Fall Symposium

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Multi-user computer system, real-time data acquisition and control; automatic experimental control; programmable calculator interface; laboratory automation; distributed processing

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

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